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**EUROPEAN PATENT APPLICATION**

**(21) Application number: 91304102.6**

**(51) Int. Cl.<sup>5</sup>: G01R 11/24**

**(22) Date of filing: 07.05.91**

**(30) Priority: 04.05.90 GB 9010091**

**(43) Date of publication of application:  
06.11.91 Bulletin 91/45**

**(84) Designated Contracting States:  
AT BE CH DE DK ES FR GB GR IT LI LU NL SE**

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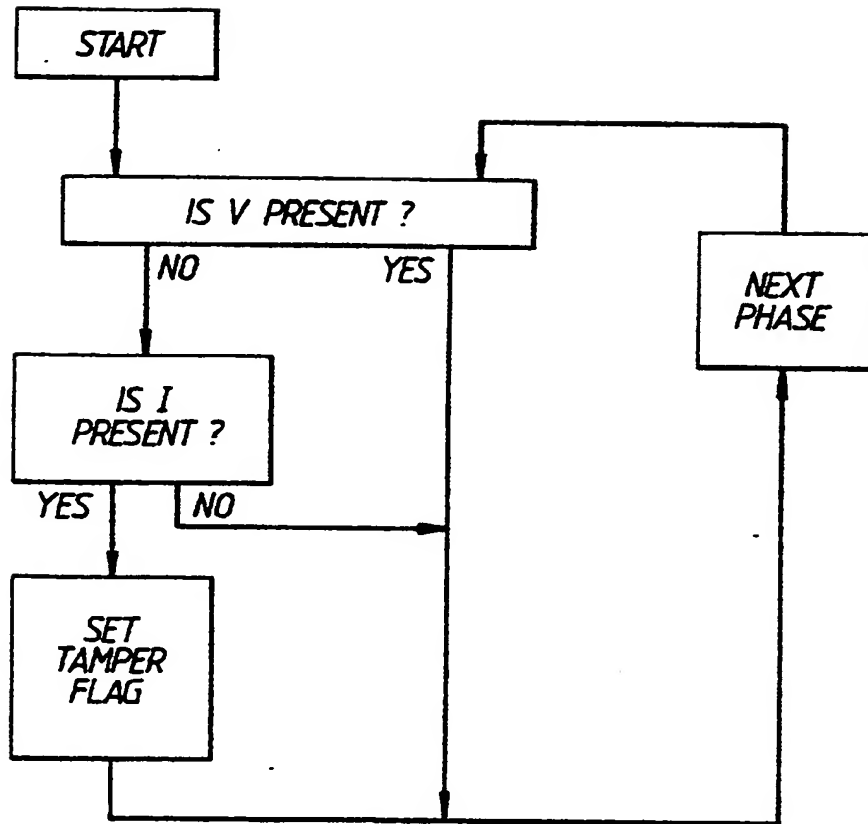
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**(54) Electricity meter tamper monitoring.**

**(57) An apparatus and method is disclosed for measuring the consumption of electricity from a mains supply which is either single or multi-phase. The apparatus and method of the invention is also able to detect when tampering with connections to the supply occurs as for instance, may be done in an attempt to reduce the quantity of energy registered as having been used.**

**In a meter which takes as inputs signals indicative of the voltage and currents present in the supply a tamper is registered whenever the voltage reading, for instance in one phase of the three-phase supply, is absent while the corresponding current is present. If both voltage and current are absent this is not registered as tampering but may be noted as a fault in the system.**

**EP 0 455 518 A2**



*Fig.2.*

This invention relates to meters which measure electrical power and energy consumption and in particular to automatically monitoring tampering with such meters.

It is known to provide a meter which uses solid state electronics to measure the electrical power and energy consumption from a mains electricity supply by, for instance, a domestic or industrial installation. Such a meter typically samples the voltage and current present in the supply and calculates from the values of these samples such quantities as the amount of energy supplied to an installation or real power, true power and volt-ampere power consumed by the load. Meters may be provided to monitor a single phase supply or a 3-phase supply, the latter being either 3-wire or 4-wire.

Inputs may be provided to such meters representative of the current and voltage present in the supply or in each phase of the supply. To provide these inputs potential transformers may be used to provide a voltage proportional to the voltage in the supply and current transformers may be used to provide a voltage proportional to the current in the supply. These transformers would generally be in the form of probes connected to the supply lines, and connected via wires to the inputs of the meter. It is also possible to use only current transformers, and not potential transformers.

In either of the above cases, there are separate wires connected to the meter which carry signals representative of the voltage and currents present in the supply. A common form of tampering with the meter in order to reduce the amount of energy registered as having been used and hence the cost payable by a consumer is to cut or otherwise isolate one or more of the potential wires to the meter. This causes a low or zero potential input to the meter.

In a 3-phase 4-wire system, assuming approximately equal loading on each of the phases, isolating one of the potential wires will cause the energy used in one of the phases not to be measured and hence reduce the measurement of energy used by one third. In practical terms, it is simpler to isolate the wires carrying the potential signal than the wires carrying the current signal.

The wire may be isolated for a given period of time, sometimes up to a week, and then re-installed before the meter is inspected, as the tamper is quite obvious. Because of this, detection of the fraud by an inspector is difficult.

The absence of a potential signal at a meter may also be due to reasons other than tampering which have no connection with the consumer whatsoever. Such an absence may be due to an electrical fault in the supply, a blown fuse, or to loosening of internal connectors due to vibrations.

Whatever the reason, the electricity supply authority may lose revenue due to the reduced registration of the energy consumption. Thus the present

invention provides Apparatus for monitoring an electricity supply to a load comprising:

first sensing means for detecting supply voltage;

second sensing means for detecting load current or power consumption by the load corresponding to the detected voltage; and means responsive to said sensed voltage and said sensed current or power consumption which indicates that tampering has occurred in the apparatus when load current or power consumption is detected in the absence of a detected voltage. A method for detecting tampering in apparatus for monitoring an electricity supply to a load of the type comprising;

first sensing means for detecting supply voltage; and

second sensing means for detecting load current or power consumption by the load corresponding to the detected voltage;

said method comprising

indicating that tampering has occurred in the case that load current or power consumption is detected in the absence of a corresponding detected voltage.

Preferably the invention stores information concerning the tampering, for instance the dates and times at which tampering occurred. The invention is equally applicable to single and poly-phase supplies and preferably in the poly-phase case stores information concerning which phases are tampered with.

A further preferred feature of the poly-phase application is the estimation of the amount of energy used but not measured due to the tampering.

An embodiment of the invention will be described by way of example with reference to the accompanying drawings, in which

Figure 1 is a diagram of an electricity supply meter according to an embodiment of the invention;

Figure 2 is a flow-diagram to illustrate the function of part of the preferred embodiment of this invention; and

Figure 3 is a flow diagram to illustrate the operation of a further embodiment of this invention.

Figure 1 shows a particular embodiment of the present invention. In the embodiment shown in figure 1 signals representative of the current and potential in each phase are derived by way of current transformers 10 and voltage transforms 12. It may be seen that in the 3-phase, 4-wire system 3 of each type of transformer is used, while in the 3-phase, 3-wire system only 2 of each type are used. The operation will be described in relation to the 3-phase, 4-wire system.

The voltage transformers 12 provide signals  $v_1$ ,  $v_2$ ,  $v_3$  which are proportional to the actual voltage in the three phases respectively. These therefore vary approximately sinusoidally. There are also provided rectified voltage signals  $V_1$ ,  $V_2$ ,  $V_3$  which are pro-

portional to the R.M.S. values of the voltage in each phase respectively.

The current transformers 10 provide signals  $I_1$ ,  $I_2$ ,  $I_3$  which produce voltages proportional to the current flowing in each phase. There are also provided signals  $A_1$ ,  $A_2$ ,  $A_3$  which are proportional to the maximum current in each phase respectively.

The functions of the electricity meter are under the control of microprocessor 1 and the detailed standard metering operation of the circuit in Figure 1 is described in EP-A-0181719. In general terms, the microprocessor takes as inputs the signals described above.  $I_1$ ,  $I_2$ ,  $I_3$ ;  $A_1$ ,  $A_2$ ,  $A_3$  and  $V_1$ ,  $V_2$ ,  $V_3$  may be input via various gain amplifiers to allow measurement in various ranges. These analog inputs are converted to digital signals in analog-to-digital converter 2. The digital inputs are sampled and the meter performs appropriate calculations to measure such quantities as real power, reactive power and maximum demand on the supply. The meter measures the electricity used in each phase by switching successively between the phases and sampling the inputs.

The electricity meter according to this invention, as well as performing the standard metering function, is also able to identify tampering with the voltage signal lines which tampering is done in an effort to reduce the amount of energy registered as having been used.

An electricity meter according to this particular embodiment of this invention is able to:

- i) identify the kind of tamper described above, i.e. the isolation of one or more of the voltage input lines  $V_1$ ,  $V_2$ ,  $V_3$  to the microprocessor;
- ii) estimate the amount of energy which is used but not directly measured due to the tamper; and
- iii) provide to an inspector or user, possibly at a later time, information concerning the time and duration of the tampering.

The function of identifying is illustrated by the flow-chart in Figure 2.

In order to identify tampering the microprocessor 1 monitors the input voltage lines  $V_1$ ,  $V_2$ ,  $V_3$  and in particular whether there is a voltage present on each phase and registers when a voltage is absent. The presence or absence of a voltage may be decided on an absolute basis, i.e. the voltage must fall to zero in order to be registered as absent, or there may be a pre-determined threshold and a voltage is registered as absent on falling below this level.

If a voltage is registered as absent in a particular phase, the microprocessor monitors whether there is current present in that phase. If there is found to be current present in the phase in which the voltage is absent a tamper flag is set in memory 3 to indicate that there is a tamper in that phase. The microprocessor then moves on to monitor the voltage in the next phase.

Thus, when the meter is next inspected, the tampering is noted, preferably together with the date and

time at which the tampering began, and the tamper flag is reset manually.

According to another embodiment, the tamper flag in memory 3 is further reset if it is found that there is neither voltage nor current present in a particular phase, and this indicates that tampering is no longer occurring. The flag may be reset in this case because the situation in which there is neither voltage nor current present in a phase is likely to be caused by a fault in the supply rather than by tampering. This is due to the fact that in practical terms, it is far simpler to isolate a voltage input line than a current input line. The tamper flag is also reset if the voltage is found to be present in a particular phase.

Preferably the microprocessor also includes means for entering information in memory 3 to indicate at what times the tamper flags for the various phases are set and reset to indicate the start and finish of tampering with the meter. This information may be read by a remote reading device or at a later stage during inspection of the meter and/or may be displayed on the meter itself. Alternatively, the memory may only store information indicating the start of the first tamper and the end of the last prior to inspection.

Thus, in summary, a tamper is registered as occurring if voltage is absent but current is present in a particular phase.

If both voltage and current are sensed as absent in the same phase, this is not registered as a tamper, but it may nevertheless be registered as having occurred for the purposes of fault checking at a later stage.

Preferably the microprocessor is also able to estimate the amount of energy used but not registered due to tampering.

Obviously it is not possible to achieve complete accuracy in estimating the amount of energy used but not registered, but it is possible to make a reasonable estimate in either of the following two ways.

The first method utilises simply the energy measured as being used in the phase or phases that have not been tampered with. If the potential in one phase is absent, the energy registered is increased by 50% to estimate the total used and this assumes that the energy used in that missing phase is the average of the energy used in the remaining phases. If the potential in two phases is absent, the energy registered is trebled to estimate the total used, and this assumes that the energy used in each phase is equal.

The second method gives a more accurate estimate of the energy used but not registered. This method uses the currents actually flowing in the phases and uses an average value of the available voltages as an estimate of the voltage in the tampered phase or phases. Thus if the potential in one phase is absent, this potential is estimated as the average of the potentials in the other two phases, and this estimate is used together with the actual current to estimate the energy used. If the potential in two phases

is absent, the potential in these phases is estimated as being the same as that in the other phase, and these estimates are used together with the actual currents to estimate the energy used.

Figure 3 illustrates the operation of an embodiment of the invention which estimate in the presence of the tamper flag the energy which is used but is not measured directly. As can be seen from figure 3, when the tamper flag is set for the first time, the meter begins to estimate the energy which is being used but not measured, and this estimation, by either of the above described methods, continues until the meter is reset at a subsequent inspection.

While the use of separate current and voltage transformers has been described in the particular embodiment above, the use of these is not essential. What is essential is that the meter is supplied with signals representative of the supply voltage and/or current and/or power consumption.

Thus the transformers may be replaced, particularly with supplies at a lower capacities, by other arrangements such as current sensing resistor which serves current directly or other suitable known arrangement, and voltage may be determined by resistive voltage divisions.

It is also possible to measure the power consumption directly, e.g. by way of Hall effect device provided that the voltage remains within a nominal range. If this is done, then there is no need to provide a separate current sensing device.

#### Claims

1. Apparatus for monitoring an electricity supply to a load comprising:
  - first sensing means for detecting supply voltage;
  - second sensing means for detecting load current or power consumption by the load corresponding to the detected voltage; and
  - means responsive to said sensed voltage and said sensed current or power consumption which indicates that tampering has occurred in the apparatus when load current or power consumption is detected in the absence of a detected voltage.
2. Apparatus as claimed in claim 1 wherein a voltage is registered as being absent if that voltage falls to zero.
3. Apparatus as claimed in claim 1 wherein a voltage is registered as being absent if that voltage falls below a pre-determined threshold.
4. Apparatus as claimed in claim 1, 2 or 3 further comprising means which sets a tamper flag in a

memory means when tampering is indicated.

5. Apparatus as claimed in claim 4 wherein the indication of tampering must be present for at least a pre-determined time in order for the tamper flag to be set.
6. Apparatus as claimed in claim 4 or 5 and further comprising means for storing in the memory means information concerning the date and time of tampering.
7. Apparatus as claimed in any preceding claim for monitoring a poly-phase electricity supply and comprising said first and second means for each of a plurality of phases and means to indicate tampering in any of the supply phases.
8. Apparatus as claimed in claim 7 and comprising means for recording in which phase or phases tampering has occurred.
9. Apparatus as claimed in claim 7 or 8 and further comprising means responsive to said sensed voltage and said load current or power consumption to calculate energy consumed by the load from the supply.
10. Apparatus as claimed in claim 9 and further comprising means for estimating the amount of energy used but not measured due to tampering.
11. Apparatus as claimed in claim 10 wherein the energy estimated assumes that the amount of energy used in each phase in which tampering is indicated is the same as the average of the energy used in the phase or phases in which no tampering is indicated.
12. Apparatus as claimed in claim 11 which is suitable for use in poly-phase circuits using the same number of wires as there are phases and wherein the energy is estimated using the actual current flowing in each phase in which tampering is indicated and correcting for phase shift by means of a look-up table.
13. Apparatus as claimed in claim 10 wherein the energy is estimated assuming that the voltage present in each phase in which tampering is indicated is the same as the average voltage in the phase or phases in which no tampering is indicated and using the actual current flowing in each phase in which tampering is indicated.
14. A method for detecting tampering in apparatus for monitoring an electricity supply to a load of the type comprising;

first sensing means for detecting supply voltage; and

second sensing means for detecting load current or power consumption by the load corresponding to the detected voltage;

said method comprising

indicating that tampering has occurred in the case that load current or power consumption is detected in the absence of a corresponding detected voltage.

15. A method as claimed in claim 14 wherein a voltage is registered as being absent if that voltage falls to zero.

16. A method as claimed in claim 14 wherein a voltage is registered as being absent if that voltage falls below a pre-determined threshold.

17. A method as claimed in claim 14, 15 or 16 further comprising setting a tamper flag in a memory means when tampering is indicated.

18. A method as claimed in claim 17 wherein the indication of tampering must be present for at least a pre-determined time in order for the tamper flag to be set.

19. A method as claimed in claim 17 or 18 further comprising storing in the memory means information concerning the date and time of tampering.

20. A method as claimed in any of claims 14-19 for detecting tampering in apparatus for monitoring a poly-phase electricity supply to a load the method comprising indicating tampering in any of the supply phases.

21. A method as claimed in claim 20 and comprising recording in which phase or phases tampering has occurred.

22. A method as claimed in claim 20 or 21 and further comprising calculating energy consumed by the load from the supply as a function of said sensed voltage and said load current or power consumption.

23. A method as claimed in claim 22 and further comprising estimating the amount of energy used but not measured due to tampering.

24. A method as claimed in claim 23 wherein the energy is estimated assuming that the amount of energy used in each phase in which tampering is indicated is the same as the average of the energy used in the phase or phases in which tam-

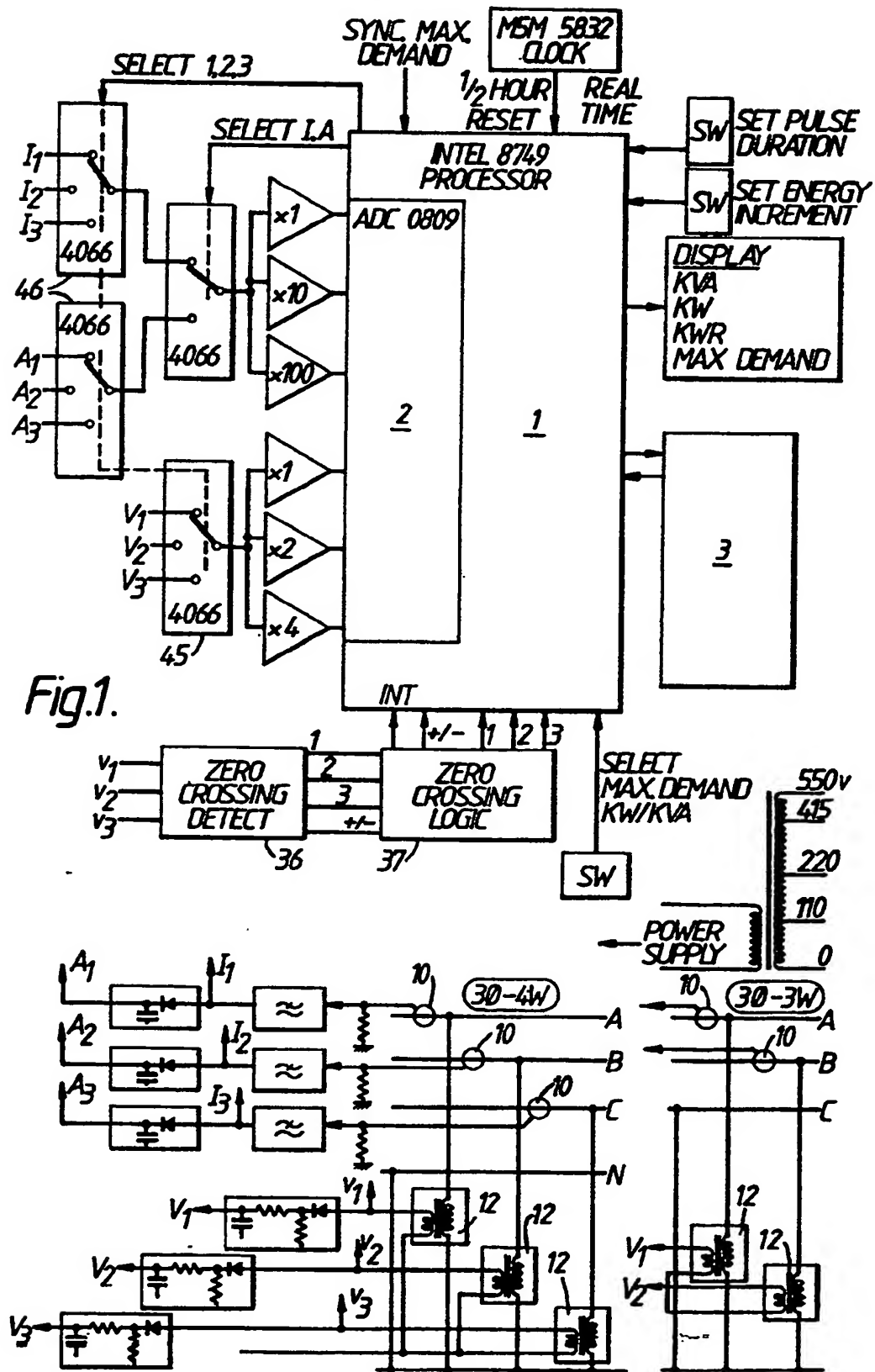
pering is not indicated.

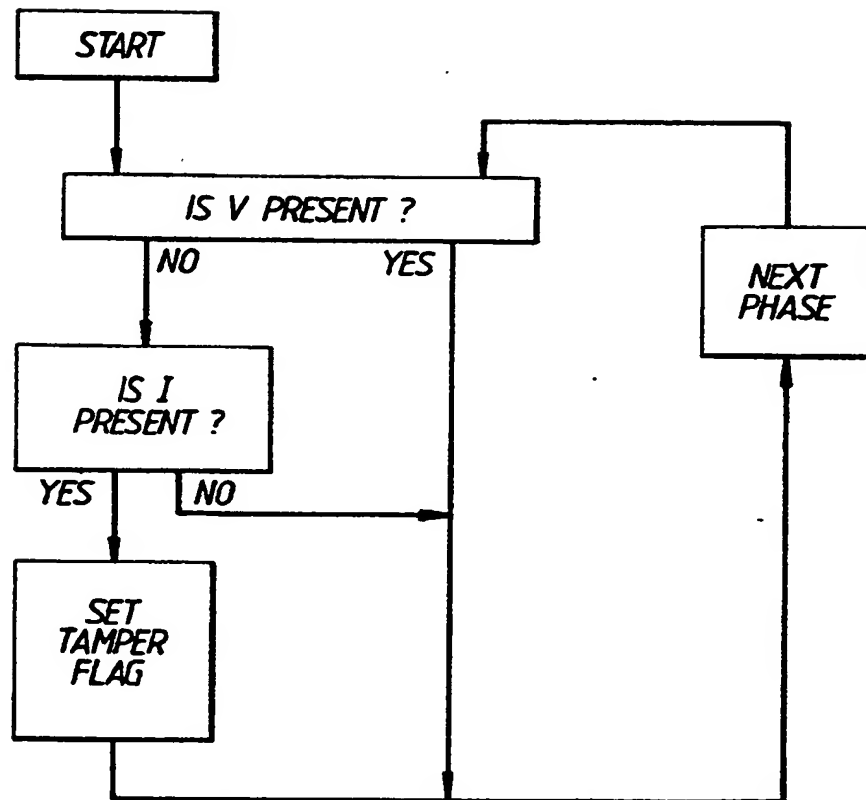
25. A method as claimed in claim 24 wherein the energy is estimated using the actual current flowing in each phase in which tampering is indicated and further comprising correcting for phase shift by means of a look-up table.

26. A method as claimed in claim 23 wherein the energy is estimated assuming that the voltage present in each phase in which tampering is indicated is the same as the average voltage in the phase or phases in which tampering is not indicated and using the actual current in each phase in which tampering is indicated.

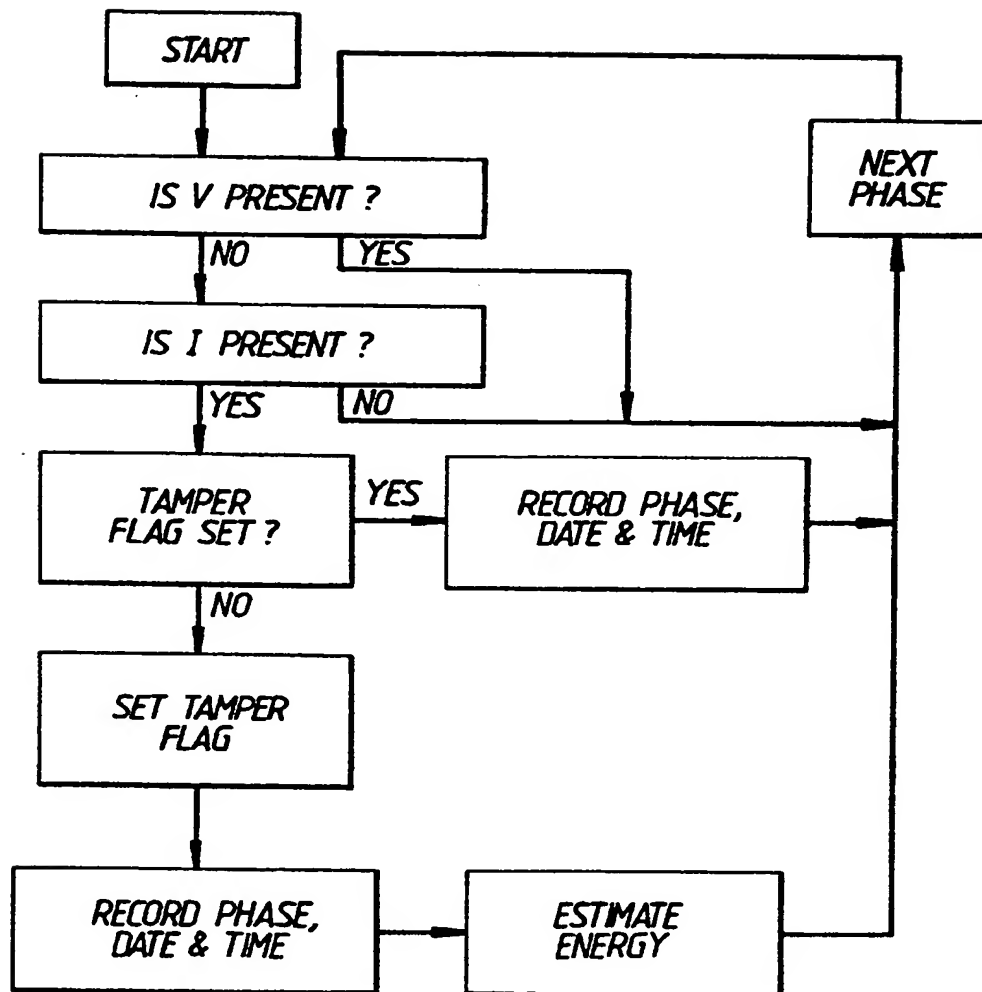
27. Apparatus for measuring electricity supply consumption substantially as hereinbefore described with reference to the accompanying drawings.

28. A method for detecting tampering in apparatus for measuring electricity supply consumption substantially as hereinbefore described with reference to the accompanying drawings.





*Fig.2.*

*Fig.3.*